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(54) METHOD AND APPARATUS FOR PROVIDING INTELLIGENT CODEC RATE ADAPTATION FOR WIRELESS USERS

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(57) **ABSTRACT**

The method includes receiving, at a network element, a media data packet sent from a first source user equipment (UE) towards a first destination UE; detecting, at the network element, congestion in at least one of a downlink channel between the network element and the first destination UE, and an uplink channel between the first source UE and the network element; identifying a second source UE that is transmitting first data to a second destination UE through the network element and has a subscriber priority level lower than the first source UE if the detecting detects congestion; sending a congestion indication that causes the second source UE to lower a rate at which the second source UE transmits the first data through the network element to the second destination UE if the detecting detects congestion; and sending the media data packet from the network element to the first destination UE.

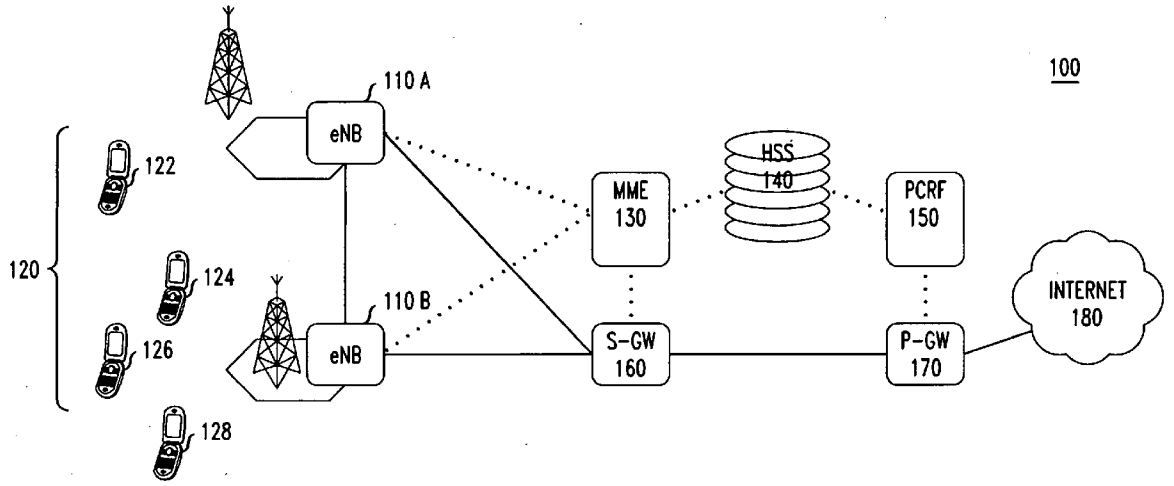


FIG. 1

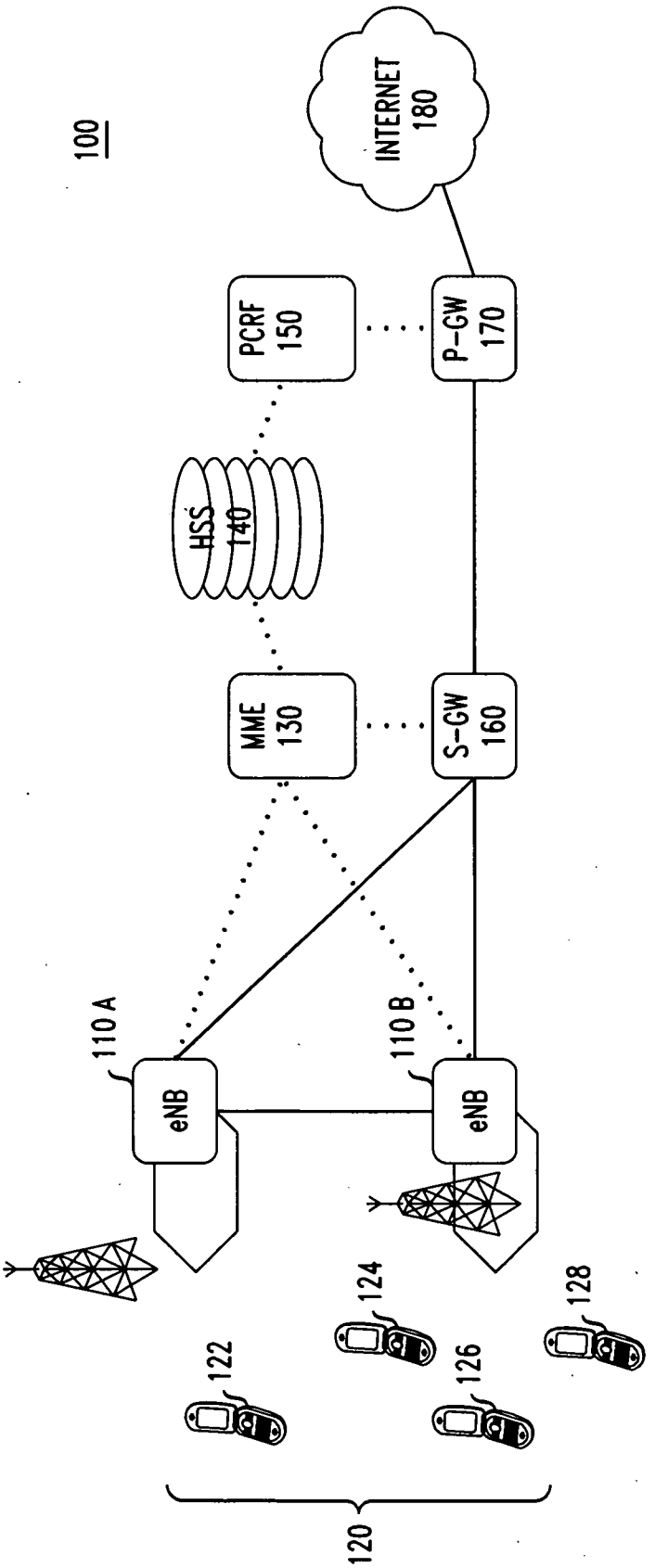

100
INTERNET 180
PCRF 150
P-GW 170
HSS 140
MME 130
S-GW 160
110 A
110 B
eNB
eNB
122
124
126
128
120

*FIG. 2*

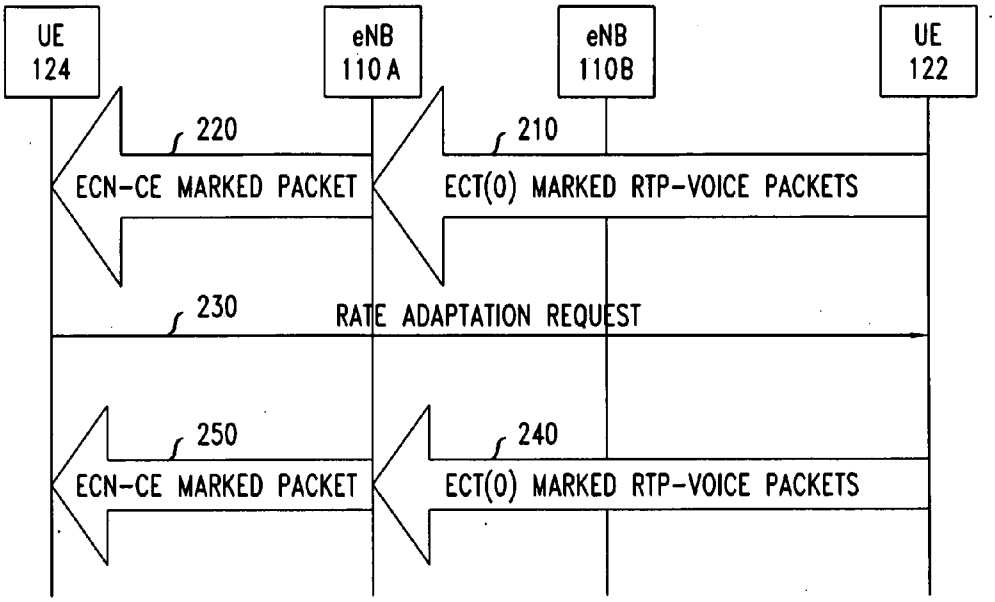

UE
124
eNB
110 A
eNB
110B
UE
122
220
ECN-CE MARKED PACKET
210
ECT(0) MARKED RTP-VOICE PACKETS
230
RATE ADAPTATION REQUEST
250
ECN-CE MARKED PACKET
240
ECT(0) MARKED RTP-VOICE PACKETS

*FIG. 3A*

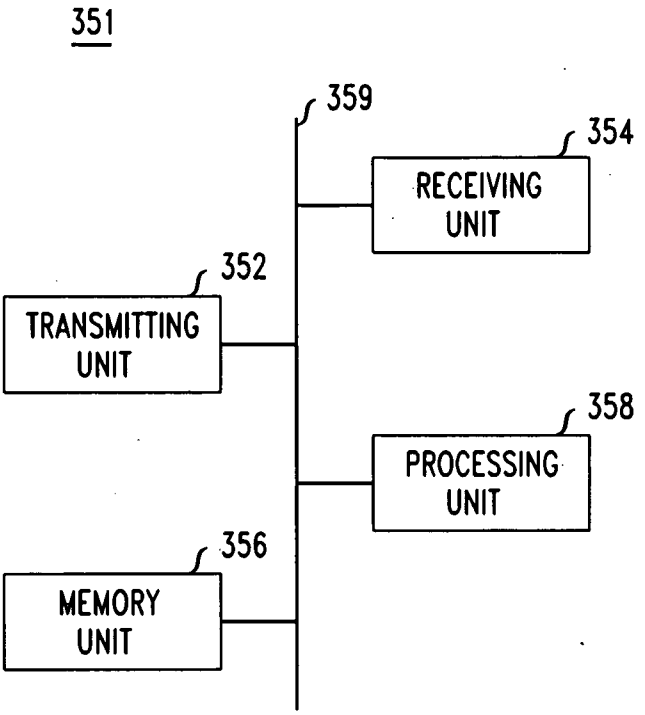

351
359
354
RECEIVING UNIT
352
TRANSMITTING UNIT
358
PROCESSING UNIT
356
MEMORY UNIT

FIG. 3B

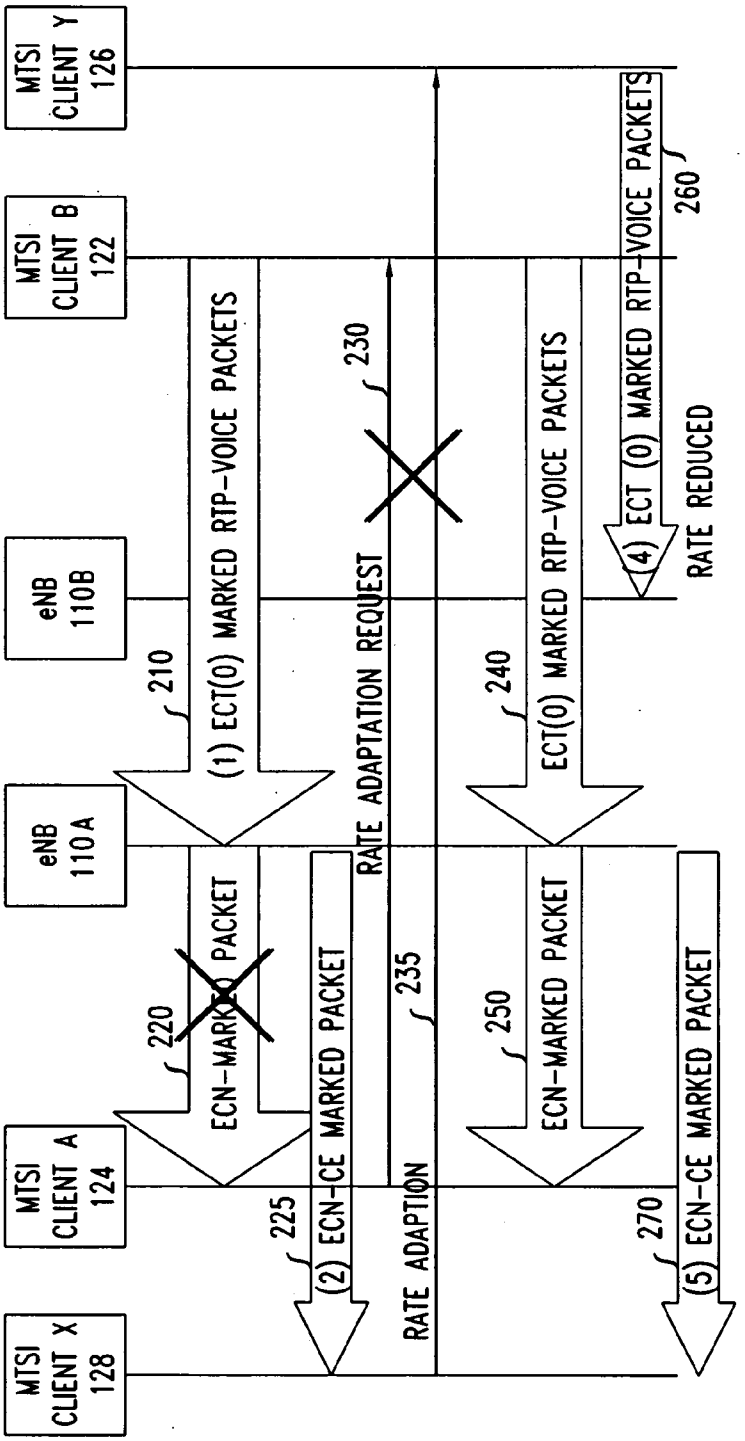
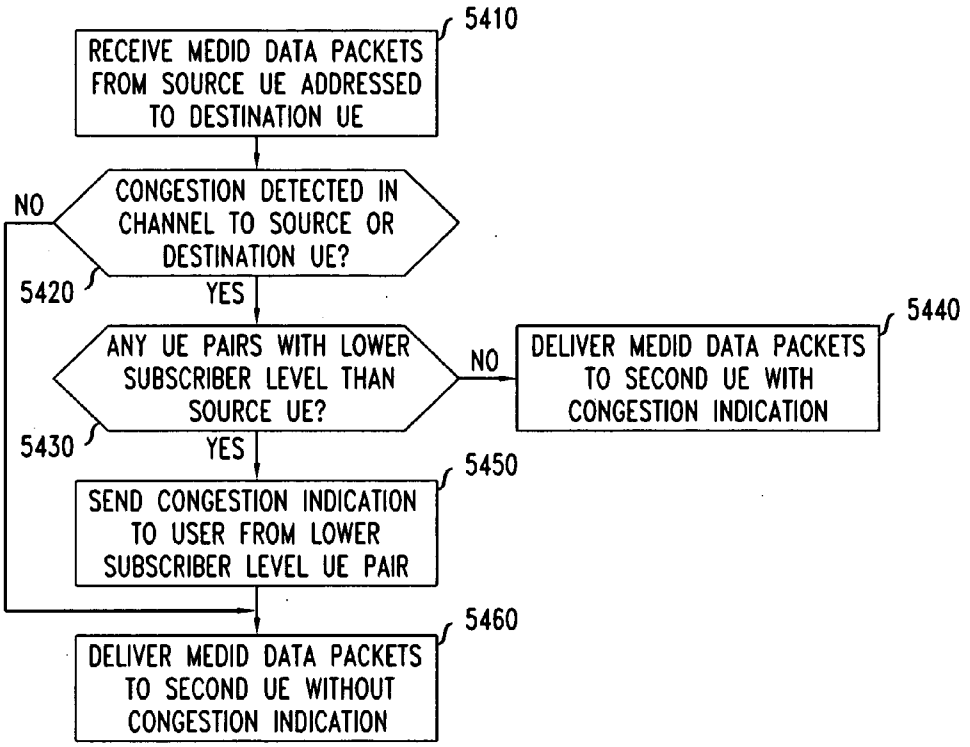

MTSI CLIENT X 128
MTSI CLIENT A 124
eNB 110A
eNB 110B
MTSI CLIENT B 122
MTSI CLIENT Y 126
(1) ECT(0) MARKED RTP-VOICE PACKETS
210
ECN-MARKED PACKET
220
(2) ECN-CE MARKED PACKET
225
RATE ADAPTATION REQUEST
230
RATE ADAPTION
235
ECT(0) MARKED RTP-VOICE PACKETS
240
ECN-MARKED PACKET
250
(4) ECT (0) MARKED RTP-VOICE PACKETS
260
RATE REDUCED
(5) ECN-CE MARKED PACKET
270

*FIG. 3C*


5410
RECEIVE MEDID DATA PACKETS FROM SOURCE UE ADDRESSED TO DESTINATION UE
CONGESTION DETECTED IN CHANNEL TO SOURCE OR DESTINATION UE?
NO
5420
YES
ANY UE PAIRS WITH LOWER SUBSCRIBER LEVEL THAN SOURCE UE?
NO
5440
DELIVER MEDID DATA PACKETS TO SECOND UE WITH CONGESTION INDICATION
5430
YES
5450
SEND CONGESTION INDICATION TO USER FROM LOWER SUBSCRIBER LEVEL UE PAIR
5460
DELIVER MEDID DATA PACKETS TO SECOND UE WITHOUT CONGESTION INDICATION

# METHOD AND APPARATUS FOR PROVIDING INTELLIGENT CODEC RATE ADAPTATION FOR WIRELESS USERS

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field

**[0002]** Example embodiments relate generally to handling codec rate adaptation for users of wireless communications networks, for example LTE networks.

**[0003]** 2. Related Art

**[0004]** In LTE, codec rates for voice are assigned initially based on factors such as device characteristics. Voice codecs for LTE include, for example, adaptive multi rate—wideband (AMR-WB), AMR7.95, and AMR5.9. Likewise, different codes rates exist for video data. The codec rate for a given call, for video or voice data, can be adapted mid-call depending on explicit congestion notifications (ECN). The specification 3GPP 23.860 describes mechanisms by which the codec rate for a video or voice stream can be lowered based on ECNs, or increased based on a lack of ECNs midstream. Currently the adaptation of codec rates for video or voice users is based on congestion notifications received for that user.

## SUMMARY OF THE INVENTION

**[0005]** One or more embodiments relate to a method and apparatus for generating handling codec rate adaptation for users of a wireless communications network.

**[0006]** According to at least one example embodiment, a method of handling congestion in a wireless communications network may include receiving, at a network element, a media data packet sent from a first source user equipment (UE) towards a first destination UE; detecting, at the network element, congestion in at least one of a downlink channel between the network element and the first destination UE, and an uplink channel between the first source UE and the network element; identifying a second source UE that is transmitting first data to a second destination UE through the network element and has a subscriber priority level lower than the first source UE if the detecting detects congestion; sending a congestion indication that causes the second source UE to lower a rate at which the second source UE transmits the first data through the network element to the second destination UE if the detecting detects congestion; and sending the media data packet from the network element to the first destination UE.

**[0007]** According to at least one example embodiment, the identifying may include determining subscriber priority levels of a plurality of UE pairs, each of the plurality of UE pairs including two UEs communicating with one another via the network element, and choosing, as the second source UE, a UE from among a UE pair having a subscriber priority level lower than the first source UE.

**[0008]** According to at least one example embodiment, the identifying may further include determining which of the plurality of UE pairs has a lowest subscriber priority level, and choosing, as the second source UE, a UE from among the UE pair having the lowest priority level.

**[0009]** According to at least one example embodiment, the sending the congestion indication may include, at the network node, inserting the congestion indication into an alternate data packet and sending the alternate data packet from the network element to the second destination UE, the alternate data packet being one of a plurality of data packets included in the first data being sent from the second source UE to the second destination UE.

**[0010]** According to at least one example embodiment, the congestion indication may be an explicit congestion notification (ECN) code point.

**[0011]** According to at least one example embodiment, the network element may be an enhanced node B (eNB) and the wireless communications network follows an LTE protocol.

**[0012]** According to at least one example embodiment, the first destination UE may be associated with the eNB and the detecting may include detecting congestion in a downlink channel between the eNB and the first destination UE.

**[0013]** According to at least one example embodiment, the first source UE may be associated with the eNB and the detecting may include detecting congestion in an uplink channel between the first source UE and the eNB.

**[0014]** According to at least one example embodiment, the media data packet may be a voice data packet or a video data packet.

**[0015]** According to at least one example embodiment, a network apparatus for handling congestion in a wireless communications network may include a data receiving unit; a data transmitting unit; a memory unit configured to store parameters corresponding with user equipment (UEs) in communication with the network element; and a processing unit coupled to the data transmitting unit, the data receiving unit, and the memory unit. The processing unit may be configured to control operations including, receiving a media data packet sent from a first source user equipment (UE) towards a first destination UE; detecting congestion in at least one of a downlink channel between the network element and the first destination UE, and an uplink channel between the first source UE and the network element; identifying a second source UE that is transmitting first data to a second destination UE through the network element and has a subscriber priority level lower than the first source UE if the detecting detects congestion; sending a congestion indication configured to cause the second source UE to lower a rate at which the second source UE transmits the first data through the network element to the second destination UE if the detecting detects congestion; and sending the media data packet from the network element to the first destination UE.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0016]** Example embodiments will become more fully understood from the detailed description provided below and the accompanying drawings, wherein like elements are represented by like reference numerals, which are given by way of illustration only and thus are not limiting and wherein:

**[0017]** FIG. **1** illustrates a portion of a wireless communications network according to at least one example embodiment.

**[0018]** FIG. **2** is a data flow diagram illustrating a method providing codec rate adaptation using explicit congestion notifications (ECNs) according to at least one example embodiment.

**[0019]** FIG. **3**A is a diagram illustrating an example structure of a network element according to at least one example embodiment.

**[0020]** FIG. **3**B is a data flow diagram illustrating a method of providing codec rate adaptation using ECNs and subscriber priority levels according to at least one example embodiment.

**[0021]** FIG. **3**C is a flow chart illustrating a method of providing codec rate adaptation using ECNs and subscriber priority levels from the perspective of a network element according to at least one example embodiment.

## DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

**[0022]** Various at least one example embodiment will now be described more fully with reference to the accompanying drawings in which some example embodiments are shown.

**[0023]** Detailed illustrative embodiments are disclosed herein. However, specific structural and functional details disclosed herein are merely representative for purposes of describing at least one example embodiment. Example embodiments may, however, be embodied in many alternate forms and should not be construed as limited to only the embodiments set forth herein.

**[0024]** Accordingly, while example embodiments are capable of various adaptations and alternative forms, embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that there is no intent to limit example embodiments to the particular forms disclosed, but on the contrary, example embodiments are to cover all adaptations, equivalents, and alternatives falling within the scope of example embodiments. Like numbers refer to like elements throughout the description of the figures. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

**[0025]** It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, there are no intervening elements present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between", "adjacent" versus "directly adjacent", etc.).

**[0026]** The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising,", "includes" and/or "including", when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

**[0027]** It should also be noted that in some alternative implementations, the functions/acts noted may occur out of the order noted in the figures. For example, two figures shown in succession may in fact be executed substantially concurrently or may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

**[0028]** As used herein, the term user equipment (UE) may be considered synonymous to, and may hereafter be occasionally referred to, as a terminal, mobile unit, mobile station, mobile user, access terminal (AT), subscriber, user, remote station, access terminal, receiver, etc., and may describe a remote user of wireless resources in a wireless communication network. The term base station (BS) may be considered synonymous to and/or referred to as a base transceiver station (BTS), NodeB, extended Node B (eNB), access point (AP), etc. and may describe equipment that provides the radio baseband functions for data and/or voice connectivity between a network and one or more users.

**[0029]** Exemplary embodiments are discussed herein as being implemented in a suitable computing environment. Although not required, exemplary embodiments will be described in the general context of computer-executable instructions, such as program modules or functional processes, being executed by one or more computer processors or CPUs. Generally, program modules or functional processes include routines, programs, objects, components, data structures, etc. that performs particular tasks or implement particular abstract data types.

**[0030]** The program modules and functional processes discussed herein may be implemented using existing hardware in existing communication networks. For example, program modules and functional processes discussed herein may be implemented using existing hardware at existing network elements or control nodes (e.g., an AP shown in FIG. **1**). Such existing hardware may include one or more digital signal processors (DSPs), application-specific-integrated-circuits, field programmable gate arrays (FPGAs) computers or the like.

**[0031]** In the following description, illustrative embodiments will be described with reference to acts and symbolic representations of operations (e.g., in the form of flowcharts) that are performed by one or more processors, unless indicated otherwise. As such, it will be understood that such acts and operations, which are at times referred to as being computer-executed, include the manipulation by the processor of electrical signals representing data in a structured form. This manipulation transforms the data or maintains it at locations in the memory system of the computer, which reconfigures or otherwise alters the operation of the computer in a manner well understood by those skilled in the art.

### Overview of Network Architecture

**[0032]** FIG. **1** illustrates a portion of a wireless communications network **100**. Wireless communications network **100** may follow, for example, an LTE protocol. Wireless communications network **100** includes a mobility management entity (MME) **110**, a first evolved node B (eNB) **110**A, a second eNB **110**B, a plurality of user equipments (UEs) **120** including first UE **122**, second UE **124**, third UE **126** and fourth UE **128**, a home subscriber server (HSS) **140**, a policy and charging rules function node (PCRF) **150**, a serving gateway (S-GW) **160**, and a public data network (PDN) gateway (P-GW) **170**.

**[0033]** The UEs **120** may be in wireless communication with either of the first eNB **110**A and the second eNB **110**B. The first eNB **110**A and the second eNB **110**B are connected to the MME **130**. Though not pictured, wireless communications network **100** may include other elements of an LTE core network in addition to MME **130**. The UEs **120** may be, for example, mobile phones, smart phones, computers, or personal digital assistants (PDAs).

**[0034]** The first eNB **110**A and the second eNB **110**B may also be connected to the serving gateway **160**. The S-GW **160** is capable of routing and forwarding user data packets of UEs connected to the first eNB **110**A or the second eNB **110**B. The S-GW **160** provides access for the first eNB **110**A and the second eNB **110**B to the P-GW **170**. The P-GW **170** provides

the first eNB **110**A and the second eNB **110**B with access to other packet data networks including, for example the internet **180**, via the serving gateway **192**. For the purpose of simplicity, the operations of the first eNB **110**A and the second eNB **110**B will be discussed primarily with reference to the first eNB **110**A. However, the second eNB **110**B is capable of operating in the same manner discussed with reference to the first eNB **110**A.

Explanation of Codec Rate Adaptation

**[0035]** UEs from among the plurality of UEs **120** may be sending voice data or video data to other UEs. UEs from among the plurality of UEs **120** sending voice data may choose a codec rate to use when sending the voice data. Higher codec rates correspond to higher fidelity voice data and a higher data rate while lower codec rates correspond to lower fidelity voice data and a lower data rate. Similarly, UEs from among the plurality of UEs **120** sending video data may choose a codec rate to use when sending the video data. The resources available within the first eNB **110**A for delivering data to and from the UEs communicating with the first eNB **110**A are limited. When the resources required to meet demands of the UEs communicating with the first eNB **110**A meet or exceed the amount of resources available to the first eNB **110**A, congestion results and data packets may be dropped by the first eNB **110**A experiencing congestion. This may result in a reduced level of quality for UEs in communication with the eNB experiencing congestion.

**[0036]** In order to prevent and/or reduce congestion experienced in the wireless communications network **100**, the wireless network **100** implements a codec rate adaptation scheme. For example, the first eNB **110**A is capable of notifying UEs when congestion is being experienced, or is expected to be experienced in the near future. For example, the first eNB **110**A may generate an indication of existing or approaching congestion using, for example, an explicit congestion notification (ECN). The ECN may be used to prompt a UE sending data via the eNB experiencing congestion to reduce the amount of data being sent by, for example, reducing a codec rate being used to send voice data, or reducing a maximum codec rate being used to send video data. The use of ECNs to prompt codec rate adaptation is discussed in the 3GPP **23.860** specification with respect to multimedia telephony services for IP multimedia subsystems (IMS) (MTSI) clients.

**[0037]** According to the 3GPP 23.860 specification, session description protocol (SDP) offer and answer procedures may be used to establish ECN usage between MTSI clients when ECN is enabled in the MTSI clients. After ECN usage has been negotiated, terminals designate voice or video media packets with the "ECT(**0**)" code point. If an eNB that supports ECN detects congestion on the downlink for a voice or video user, the eNB may designate ECT-marked downlink packets with the "ECN-CE" code point to indicate "congestion experienced". The ECN-CE marked packet indicates to the MTSI client receiving the packet that it may be necessary to request new codec rates for the sender of the packet. The receiving MTSI client may determine which rate to request using, for example, known procedures described in the 3GPP specification TS 26.114. If the receiving MTSI client determines a rate request is necessary, the receiving MTSI client sends a rate request to the sending MTSI client requesting the sending MTSI client to use a lower transmission rate. For voice data, the rate request may request the use of a codec which has a lower code rate than a codec currently being used. For video data sent using an adaptive bit rate, the rate request may request the use of a lower maximum bit rate. A process for lowering congestion by using ECNs to effect codec rate adaptation will now be discussed below with reference to FIG. **2**.

**[0038]** FIG. **2** is a data flow diagram illustrating a method providing codec rate adaptation using ECNs. The method illustrated in FIG. **2** is based on the 3GPP 23.860 specification.

**[0039]** FIG. **2** will be explained with reference to a scenario in which the first UE **122** and the second UE **124** are participating in a voice call, the second UE **124** is associated with the first eNB **110**A, and the first eNB **110**A detects congestion in the downlink to the second UE **124**. The first UE **122**, the second UE **124** and the first eNB **110**A each support ECN. The first and second UEs **122** and **124** may be, for example, MTSI clients.

**[0040]** Referring to FIG. **2**, the first UE **122** sends voice packets **210** marked with the code point ECT(**0**) towards the second UE **124**. The voice packets are received by the eNB associated with the second UE **124**, the first eNB **110**A. Because the first eNB **110**A detects congestion on the downlink channel to the second UE **124**, the first eNB changes the code point of one or more of the voice packets to the ECN-CE code point, and sends the one or more ECN-CE marked packets **220** to the UE **124**. After receiving the ECN-CE marked packets **220**, the second UE **124** determines whether or not to request a codec rate change from the sender of the ECN-CE marked voice packet, the first UE **122**. In the example illustrated in FIG. **2**, the second UE **124** determines that a rate change is needed. Accordingly, the second UE **124** sends a rate adaptation request **230** to the first UE **122**. In response, the first UE **122** lowers the codec rate used by the first UE **122** to send voice data packets to the second UE **124**. The first UE **122** then sends, towards the second UE **124**, voice packets **240** that are marked with the code point ECT(**0**) and have a reduced codec rate with respect to the previously sent voice packets **210**. The first eNB **110**A may determine that the downlink channel to the second UE **124** is still congested. Accordingly, the first eNB **110** may, again, change the code point of the voice packets to the ECN-CE code point, and send one or more ECN-CE marked packets **250** to the second UE **124**.

**[0041]** Accordingly, in the method of using ECNs to handle network congestion illustrated in FIG. **2**, once the first eNB **110**A detects congestion in the downlink channel to the second UE **124**, the first eNB **110**A may generate an indication, the ECN-CE marked packet **220**, which causes the second UE **124** to request a rate adaptation from the first UE **122**.

**[0042]** Further, though FIG. **2** is discussed with respect to an example in which congestion is detected in the downlink channel between the second UE **124** and the first eNB **110**A, ECNs may also be generated if congestion is detected in the uplink channel between the second UE **124** and the first eNB **110**A. For example, if the first eNB **110**A detects congestion in the uplink channel, the first eNB **110**A may modify an uplink packet sent from the second UE **124** towards the first UE **122** via the first eNB **110**A to include the ECN-CE code point. Upon receipt at the first UE **122**, the ECN-CE marked packet would prompt the first UE **122** to send a rate adaptation request to the second UE **124**. In response, the second UE **124** would lower the codec rate used by the second UE **124** to send voice data packets to the first UE **122**.

**[0043]** In both cases of uplink congestion and downlink congestion a rate adaptation request is sent and the UE receiving the rate adaptation request responds to the rate adaptation request by using a lower, less data intensive, codec rate to send subsequent voice data to the other UE. Accordingly, in both cases, the experienced congestion may be reduced.

**[0044]** Additionally, though, for the purpose of simplicity, the method of FIG. **2** is discussed with reference only to a voice call in which voice packets are sent between the first UE **122** and the second UE **124**, the method also applies to video data. For example, if the first UE **122** is sending video data to the second UE **124** via the first eNB **110**A, and the first eNB **110**A detects congestion in the downlink channel between the first eNB **110**A and the second UE **124**, the first eNB **110**A may prompt the second UE **124** to send a rate adaptation request to the first UE **122** by modifying a video data packet sent from the first UE **122** towards the second UE **124** to include the ECN-CE code point. The first UE **122** may respond to the rate adaptation request by lowering a maximum bit rate used to encode the video data being sent to the second UE **124**.

**[0045]** Likewise, if the second UE **124** is sending video data to the first UE **122** via the first eNB **110**A, and the first eNB **110**A detects congestion in the uplink channel between the first eNB **110**A and the second UE **124**, the first eNB **110**A may prompt the first UE **122** to send a rate adaptation request to the second UE **124** by modifying a video data packet sent from the second UE **124** towards the first UE **122** to include the ECN-CE code point. The second UE **124** may respond to the rate adaptation request by lowering a maximum bit rate used to encode the video data being sent to the first UE **122**.

Method and Apparatus for Providing Codec Rate Adaptation Using ECNs and Subscriber Priority Levels

**[0046]** As is described above with reference to FIGS. **1** and **2**, ECNs may be used to reduce codec rates of voice data senders. Accordingly, an amount of data being sent through, and thus an amount of congestion experienced by, the wireless communications network **100** may be reduced.

**[0047]** However, in the method illustrated above in FIG. **2**, the process of reducing the codec rate of a given voice user does not consider information available on the first eNB **110**A regarding other users, such as whether they are high priority voice users or guaranteed bit rate (GBR) video users (e.g., paying users), or lower priority voice or data users (e.g., non-paying users). For example, LTE networks provide for classification of subscribers into different subscriber priority levels. Examples of subscriber levels include gold, silver and bronze subscriber priority levels. The rank of a subscriber priority level may indicate, for example, a cost of the service paid for by a subscriber. Accordingly, subscribers with gold subscriber priority levels may be subscribers who pay a higher fee for a quality of experience (QoE) higher than subscribers having silver and bronze subscriber priority levels users. Likewise, subscribers with silver subscriber priority levels may be subscribers who pay a higher fee for a QoE higher than subscribers having bronze subscriber priority levels users.

**[0048]** Thus, when making decisions about allocating limited network resources of the communications network **100** to users of the wireless communications network **100** including, for example, decisions about lowering voice or video data codec rates for certain users, it may be desirable to take into account relative subscriber priority levels of the users. This way, when allocating the limited resources of the wireless network **100**, a QoE of subscribers with higher subscriber priority levels can be maintained if possible.

**[0049]** As a result, current gold level users may be more likely to choose to continue paying the higher fees associated with the gold subscriber priority level. Further, bronze and silver level users may be more likely to choose to increase their fees by paying higher fees to become gold level subscribers.

**[0050]** A method for lowering congestion by using ECNs to effect codec rate adaptation while taking into account users' subscriber priority levels will now be discussed below with reference to FIGS. **3**A-**3**C.

**[0051]** FIG. **3**A is a diagram illustrating an example structure of a network element **301**. According to at least one example embodiment, either or both of the first eNB **110**A and the second eNB **110**B may have the structure and operation of the network element **301** described below. Referring to FIG. **3**A, the network element **301** may include, for example, a data bus **359**, a transmitting unit **352**, a receiving unit **354**, a memory unit **356**, and a processing unit **358**.

**[0052]** The transmitting unit **352**, receiving unit **354**, memory unit **356**, and processing unit **358** may send data to and/or receive data from one another using the data bus **359**. The transmitting unit **352** is a device that includes hardware and any necessary software for transmitting wired and/or wireless signals including, for example, data signals and control signals, via one or more wired and/or wireless connections to other network elements in the wireless communications network **100**. For example, data and/or control signals may include voice data packets having the "ECT(**0**)" or "ECN-CE" code points.

**[0053]** The receiving unit **354** is a device that includes hardware and any necessary software for receiving wired and/or wireless signals including, for example, data signals and control signals, via one or more wired and/or wireless connections to other network elements in the wireless communications network **100**.

**[0054]** The memory unit **356** may be any device capable of storing data including magnetic storage, flash storage, etc.

**[0055]** The processing unit **358** may be any device capable of processing data including, for example, a microprocessor configured to carry out specific operations based on input data, or capable of executing instructions included in computer readable code.

**[0056]** For example, the processing unit **358** is capable of determining subscriber priority levels of subscribers associated with each of the UEs, from among the UEs **120**, in communication with the network element **301**. Further, the processing unit is capable of comparing subscriber priority levels associated with two or more UEs to determine which UE is associated with the highest subscriber priority level.

**[0057]** Example methods for operating the network element **301**, the first eNB **110**A, and the second eNB **110**B will now be discussed in greater detail below with reference to FIGS. **3**B and **3**C.

**[0058]** According to at least one example embodiment, each of the operations illustrated in, or described with respect to, FIGS. **3**B and **3**C as being performed by an eNB may be performed by, for example, one or more eNBs having the structure of the network element **301** as illustrated in FIG. **3**A. For example, the memory unit **356** may store executable instructions corresponding to each of the operations described below with reference to in FIGS. **3**B and **3**C. Fur-

ther, the processor unit **158** may be configured perform each of the operations described below with respect to FIGS. **3**B and **3**C. Further, according to at least one example embodiment, transmitted data and/or control signals may be transmitted through the transmitting unit **352**, and received data and/or control signals may be received through the receiving unit **354**.

**[0059]** FIG. **3**B is a data flow diagram illustrating a method of providing codec rate adaptation using ECNs and subscriber priority levels according to at least one example embodiment.

**[0060]** Like FIG. **2**, FIG. **3**B will be explained with reference to a scenario in which the first UE **122** and the second UE **124** are participating in a voice call, the second UE **124** is associated with the first eNB **110**A, and the first eNB **110**A detects congestion in the downlink to the second UE **124**. Further, the third UE **126** and the fourth UE **128** are also participating in a voice call, the fourth UE **128** is associated with the first eNB **110**A, and the third and fourth UEs **126** and **128** are both associated with subscribers having lower subscriber priority levels than the first UE **122**. The first UE **122**, the second UE **124**, the third UE **126**, the fourth UE **128** and the first eNB **110**A each support ECN. The first through fourth UEs **122**~**128** may be, for example, MTSI clients.

**[0061]** Referring to FIG. **3**B, the first UE **122** sends the voice packets **210** marked with the code point ECT(**0**) towards the second UE **124**. The voice packets **210** are received by the eNB associated with the second UE **124**, the first eNB **110**A. As in FIG. **3**B, the first eNB **110**A detects congestion on the downlink channel to the second UE **124**. However, instead of simply marking the voice packets of the first UE **124** with the ECN-CE code point, the first eNB **110**A determines whether or not there is another UE that is better suited to experience a decreased codec rate than the first UE **122**. For example, the first eNB **110**A may obtain information regarding the subscriber priority level of each of the first through fourth UEs **122**~**128** according to known methods. The first eNB **110**A then uses the subscriber priority level information to determine that the third UE **126** and the fourth UE **128** are two UEs currently participating in a voice call via the first eNB **110**A that have subscriber priority levels lower than that of the first UE **122**. Then, instead of sending the ECN-CE marked packet **220** to the second UE **124**, the first eNB **110** sends an ECN-CE marked packet **225** to the fourth UE **128**. The first eNB **110** may send the voice packets **210** to the second UE **128** without including the ECN-CE code point.

**[0062]** After receiving the ECN-CE marked packets **225**, the fourth UE **128** determines whether or not to request a codec rate change from the sender of the ECN-CE marked voice packet, the third UE **126**, according to known methods. In the example illustrated in FIG. **3**, the fourth UE **128** determines that a rate change is needed. Accordingly, the fourth UE **128** sends a rate adaptation request **235** to the third UE **126**. In response, the third UE **126** lowers the codec rate it uses to send voice data packets to the fourth UE **128**. The third UE **126** then sends, towards the second UE **124**, voice packets **260** that are marked with the code point ECT(**0**) and have a reduced codec rate with respect to a previous codec rate of the third UE **126**. Further, the first UE **122** may send additional voice packets **240** towards the second UE **124**. The first eNB **110**A may determine that the downlink channel to the second UE **124** is still congested. Accordingly, the first eNB **110**A may, again, determine that the third and fourth UEs **126** and **128** have lower subscriber priority levels than the first UE **122**, change the code point of voice packets being sent from the third UE **126** to the forth UE **128** to the ECN-CE code point, and send the ECN-CE marked packets **270** to the fourth UE **128**.

**[0063]** Accordingly, in the method of using ECNs to handle network congestion illustrated in FIG. **3**, once the first eNB **110**A detects congestion in the downlink channel to the second UE **124**, the first eNB **110**A may generate an indication, the ECN-CE marked packet **225**, which causes the fourth UE **128** to request a rate adaptation from the third UE **126**. Because the third UE **126** responds to the rate adaptation request by using a lower, less data intensive, codec rate to send subsequent voice data to the fourth UE **128**, the overall amount of data being handled in the wireless communications network **100** by the first eNB **110**A may be reduced. Accordingly, overall congestion experienced by UEs in communication with the first eNB **110**A may be reduced. Accordingly, a reduction in congestion may be achieved without requiring the UE associated with the higher subscriber priority level, the first UE **122**, to assume a lower codec rate and generate voice packets having a lower level of fidelity, thus lowering the QoE for the first UE **122** and the second UE **124**.

**[0064]** Further, though FIG. **3**B is discussed with respect to an example in which congestion is detected in the downlink channel between the second UE **124** and the first eNB **110**A, according to at least one example embodiment, ECNs may also be generated and sent to low level users if congestion is detected in the uplink channel between the second UE **124** and the first eNB **110**A. For example, if the first eNB **110**A detects congestion in the uplink channel, the first eNB **110**A may determine that the third and fourth UEs **126** and **128** have lower subscriber priority levels than the first UE **122**. The first eNB **110**A may then modify an uplink packet sent from the fourth UE **128** towards the third UE **126** via the first eNB **110**A to include the ECN-CE code point. Upon receipt at the third UE **126**, the ECN-CE marked packet would prompt the third UE **126** to send a rate adaptation request to the fourth UE **128**. In response, the fourth UE **128** would lower the codec rate used by the fourth UE **128** to send voice data packets to the third UE **126**.

**[0065]** FIG. **3**C is a flow chart illustrating a method of providing codec rate adaptation using ECNs and subscriber priority levels from the perspective of a network element. FIG. **3**C will be explained with reference to both a downlink case where the first eNB **110**A handles potential congestion in a downlink channel between the first eNB **110**A and the second UE **124**, and an uplink case where the first eNB **110**A handles potential congestion in an uplink channel between the second UE **124** and the first eNB **110**A. Though, for the purpose of simplicity, FIG. **3**C is described below with reference only to the first eNB **110**A, the operations described below may also be performed by the second eNB **110**B.

**[0066]** Referring to FIG. **3**C, in step S**410**, one or more media data packets addressed to a destination UE are received from a source UE. For example, in a downlink case, the first UE **122** may be the source UE and the first eNB **110**A may receive, from the first UE **122**, one or more media data packets addressed to the second UE **124**. In an uplink case, the second UE **124** may be the source UE and the first eNB **110**A may receive, from the second UE **124**, one or more media data packets addressed to the first UE **122**. The one or more media data packet may be, for example, voice data packets or video

data packets. The one or more media data packets may include ECT(**0**) code points indicating that the source UE is ECN capable.

**[0067]** In step S**420**, a congestion determination is made by the eNB. For example, in the downlink case, a determination may be made regarding whether or not congestion exists on the downlink channel between the first eNB **110**A and the second UE **124**. In the uplink case, a determination may be made regarding whether or not congestion exists on the uplink channel between the second UE **124** and the first eNB **110**A. The first eNB **110**A may determine whether or not congestion exists on the downlink channel or the uplink channel with the first UE **124** according to known methods.

**[0068]** If congestion is not determined to exist in step S**420**, the first eNB **110**A may proceed to step S**460**.

**[0069]** In step S**460**, the voice packets received from the source UE are delivered to the destination UE without adding a congestion indication, and the process may end. For example, in the downlink case, the first eNB **110**A may forward the media data packets received from the first UE **122** in step S**410** to the second UE **124** without changing a code point of the received media data packets from the ECT(**0**) code point to the ECN-CE code point. In the uplink case, the first eNB **110**A may forward the media data packets received from the second UE **124** in step S**410** to the first UE **122** without changing a code point of the received voice packets from the ECT(**0**) code point to the ECN-CE code point.

**[0070]** Returning to step S**420**, if the first eNB **110**A determines that congestion does exist on the downlink channel to the second UE **124** in the downlink case, or congestion exists in the uplink channel from the second UE **124** in the uplink case, the first eNB **110**A may proceed to step S**430**.

**[0071]** In step S**430**, a determination is made regarding whether or not any UE pairs exist having subscriber priority levels lower than the subscriber priority level of the source UE. For example, in the downlink case, the first eNB **110**A may determine whether or not there are any UE pairs communicating via the first eNB **110**A which have subscriber priority levels lower than that of the first UE **122**. For example, the eNB **110**A may determine the subscriber priority levels (e.g., gold, silver or bronze) of each UE participating in a voice communication with another UE via the first eNB **110**A. The first eNB may consider each set of two UEs communicating with one another via the first eNB **110**A to be a UE pair. The first eNB **110** may then compare the subscriber priority level of the first UE **122** to the subscriber priority levels of the identified UE pairs to determine if any UE pairs exist having lower subscriber priority levels than the first UE **122**.

**[0072]** Likewise, in the uplink case, the first eNB **110** may compare the subscriber priority level of the second UE **124** to the subscriber priority levels of the identified UE pairs to determine if any UE pairs exist having lower subscriber priority levels than the second UE **124**.

**[0073]** For example, the first eNB **110**A may consider a highest subscriber priority level associated with either of the UEs in each UE pair to be the subscriber priority level for the UE pair. For example, if a UE pair includes a UE associated with a gold subscriber priority level communicating with a UE associated with a silver subscriber priority level, the eNB **110**A may consider the subscriber priority level of the UE pair to be gold. The first eNB **110**A may obtain subscriber priority level information for one or more UEs in communication with the eNB **110**A according to know methods.

**[0074]** If, in step S**430**, no UE pairs with subscriber priority levels lower than that of the source UE are identified, the first eNB **110**A proceeds to step S**440**.

**[0075]** In step S**440** the media data packets received in step S**410** from the source UE are delivered to the destination UE with a congestion indication.

**[0076]** The congestion indication sent by the first eNB **110**A in step S**440** may be anything which is capable of indicating the existence of congestion in the wireless network communication network **100**. For example, in the downlink case, the first eNB **110**A may change the code point of the media data packets received from the first UE **122** from the ECT(**0**) code point to the ECN-CE code point thus indicating the presence of congestion in the downlink channel between the first eNB **110**A and the second UE **124**. In the uplink case, the first eNB **110**A may change the code point of the media data packets received from the second UE **124** from the ECT (**0**) code point to the ECN-CE code point thus indicating the presence of congestion in the uplink channel between the second UE **124** and the first eNB **110**A.

**[0077]** The destination UE may respond to the ECN-CE marked voice packet by sending a codec rate adaptation request to the source UE. The source UE may respond to the rate adaptation request by lowering a codec rate used to send subsequent voice packets to the destination UE, thus reducing the amount of network resources needed to deliver subsequent voice packets from the source UE to the destination UE.

**[0078]** Returning to step S**430**, if one or more UE pairs are identified which has a subscriber priority level lower than that of the source UE, the first eNB **110**A proceeds to step S**450**.

**[0079]** In step S**450**, a congestion indication is sent to at least one of the one or more UE pairs identified in step S**430** as having a subscriber priority level lower than that of the source UE.

**[0080]** For example, in the downlink case, the third UE **126** may be sending media data packets to the fourth UE **128** via the first eNB **110**A. Further, in step S**430**, the first eNB **110**A may identify a UE pair including the third UE **126** and the fourth UE **128** as a UE pair having a lower subscriber priority level than the source UE, first UE **122**. Accordingly, in step S**450**, the first eNB **110**A may send a congestion indication to the fourth UE **128**.

**[0081]** The congestion indication sent by the first eNB **110**A in step S**450** may be anything which is capable of indicating the existence of congestion in the wireless network communication network **100**. For example, the first eNB **110**A may change the code point of a media data packet received from the third UE **126** from the ECT(**0**) code point to the ECN-CE code point. As is illustrated above in FIG. **3**B, the fourth UE **128** may respond to the ECN-CE marked media data packet by sending a codec rate adaptation request to the third UE **126**. The third UE **126** may respond to the rate adaptation request by lowering a codec rate used to send subsequent voice packets to the fourth UE **128**, thus reducing the amount of network resources needed to deliver subsequent voice packets from the third UE **126** to the fourth UE **128**, and the amount of network resources being used by the first eNB **110**A. Accordingly, a reduction in network congestion may be achieved without reducing a QoE of the first UE **122**.

**[0082]** In the uplink case, the fourth UE **128** may be sending media data packets to the third UE **126** via the first eNB **110**A. Further, in step S**430**, the first eNB **110**A may identify a UE pair including the third UE **126** and the fourth UE **128** as

a UE pair having a lower subscriber priority level than the source UE, first UE **122**. Accordingly, in step **S450**, the first eNB **110**A may send a congestion indication to the third UE **126** by, for example, adding an ECN-CE code point to a media data packet sent from the fourth UE **128** to the third UE **126**. The third UE **126** may respond to the ECN-CE marked media data packet by sending a codec rate adaptation request to the fourth UE **128**. The fourth UE **128** may respond to the rate adaptation request by lowering a codec rate used to send subsequent voice packets to the third UE **126**.

**[0083]** According to at least one example embodiment, if in step **S430**, the first eNB **110**A identifies multiple UE pairs having a lower priority level than the source UE, then in step **S450**, the first eNB **110**A may choose, as the UE pair to which to send the congestion notification, the UE pair having the lowest subscriber priority level from among all the identified UE pairs.

**[0084]** After step **S450**, the first eNB **110**A may proceed to step **S460** and deliver the media data packets received from the source UE in step **S410** to the destination UE without adding a congestion indication.

**[0085]** Accordingly, using the method of providing codec rate adaptation using ECNs and subscriber priority levels discussed above with reference to FIG. **3**C, congestion detected by an eNB in either an uplink channel or a downlink channel for transmitting media data packets may be mitigated while removing or reducing the need to lower a voice and/or video codec rate for high priority subscribers.

**[0086]** Example embodiments being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from example embodiments, and all such modifications are intended to be included within the scope of example embodiments.

What is claimed:

**1**. A method of handling congestion in a wireless communications network, the method comprising:

receiving, at a network element, a media data packet sent from a first source user equipment (UE) towards a first destination UE;

detecting, at the network element, congestion in at least one of a downlink channel between the network element and the first destination UE, and an uplink channel between the first source UE and the network element;

identifying a second source UE that is transmitting first data to a second destination UE through the network element and has a subscriber priority level lower than the first source UE if the detecting detects congestion;

sending a congestion indication that causes the second source UE to lower a rate at which the second source UE transmits the first data through the network element to the second destination UE if the detecting detects congestion; and

sending the media data packet from the network element to the first destination UE.

**2**. The method of claim **1**, wherein the identifying includes determining subscriber priority levels of a plurality of UE pairs, each of the plurality of UE pairs including two UEs communicating with one another via the network element, and choosing, as the second source UE, a UE from among a UE pair having a subscriber priority level lower than the first source UE.

**3**. The method of claim **2**, wherein the identifying further includes,

determining which of the plurality of UE pairs has a lowest subscriber priority level, and

choosing, as the second source UE, a UE from among the UE pair having the lowest priority level.

**4**. The method of claim **1**, wherein the sending the congestion indication includes, at the network node, inserting the congestion indication into an alternate data packet and sending the alternate data packet from the network element to the second destination UE, the alternate data packet being one of a plurality of data packets included in the first data being sent from the second source UE to the second destination UE.

**5**. The method of claim **4**, wherein the congestion indication is an explicit congestion notification (ECN) code point.

**6**. The method of claim **1**, wherein the network element is an enhanced node B (eNB) and the wireless communications network follows an LTE protocol.

**7**. The method of claim **6**, wherein the first destination UE is associated with the eNB and the detecting includes detecting congestion in a downlink channel between the eNB and the first destination UE.

**8**. The method of claim **6**, wherein the first source UE is associated with the eNB and the detecting includes detecting congestion in an uplink channel between the first source UE and the eNB.

**9**. The method of claim **1**, wherein the media data packet is a voice data packet or a video data packet.

**10**. A network apparatus for handling congestion in a wireless communications network, the apparatus comprising:

a data receiving unit;

a data transmitting unit;

a memory unit configured to store parameters corresponding with user equipment (UEs) in communication with the network element; and

a processing unit coupled to the data transmitting unit, the data receiving unit, and the memory unit and configured to control operations including,

receiving a media data packet sent from a first source user equipment (UE) towards a first destination UE;

detecting congestion in at least one of a downlink channel between the network element and the first destination UE, and an uplink channel between the first source UE and the network element;

identifying a second source UE that is transmitting first data to a second destination UE through the network element and has a subscriber priority level lower than the first source UE if the detecting detects congestion;

sending a congestion indication configured to cause the second source UE to lower a rate at which the second source UE transmits the first data through the network element to the second destination UE if the detecting detects congestion; and

sending the media data packet from the network element to the first destination UE.

**11**. The network apparatus of claim **10**, wherein the processor is configured to control the identifying such that the identifying includes determining subscriber priority levels of a plurality of UE pairs, each of the plurality of UE pairs including two UEs communicating with one another via the network element, and choosing, as the second source UE, a UE from among a UE pair having a subscriber priority level lower than the first source UE.

**12**. The network apparatus of claim **11**, wherein the processor is further configured to control the identifying such that the identifying further includes,

determining which of the plurality of UE pairs has a lowest subscriber priority level, and

choosing, as the second source UE, a UE from among the UE pair having the lowest priority level.

**13**. The network apparatus of claim **10**, wherein the processor is configured to control the sending the congestion indication such that the sending the congestion indication includes inserting the congestion indication into an alternate data packet and sending the alternate data packet from the network element to the second destination UE, the alternate data packet being one of a plurality of data packets included in the first data being sent from the second source UE to the second destination UE.

**14**. The network apparatus of claim **13**, wherein the congestion indication is an explicit congestion notification (ECN) code point.

**15**. The network apparatus of claim **10**, wherein the network element is an enhanced node B (eNB) and the wireless communications network follows an LTE protocol.

**16**. The network apparatus of claim **15**, wherein the first destination UE is associated with the eNB and the processor is configured to control the detecting such that the detecting includes detecting congestion in a downlink channel between the eNB and the first destination UE.

**17**. The network apparatus of claim **15**, wherein the first source UE is associated with the eNB and the processor is configured to control the detecting such that the detecting includes detecting congestion in an uplink channel between the first source UE and the eNB.

**18**. The network apparatus of claim **10**, wherein the media data packet is a voice data packet or a video data packet.

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